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Design and Analysis Special Shaped Milling Cutter Using Finite Element Analysis

K. Chaitanya[1], M. Kaladhar[2]
[1](Mechanical Raghu college of engineering, JNTU Kakinada, India)
[2](Department of mechanical engineering, Raghu College of engineering, JNTU Kakinada India)

ABSTRACT: *Milling is a production process which is based on material removal using multipoint cutting tools, as a result higher material removal rates can be achieved along with high surface finish. The common operations performed on milling machine are: facing, shaping, slot cutting, drilling, T-slot cutting etc. This paper presents an indiscriminate model of Special Shaped milling cutter made of high speed steel material for the purpose of predicting stress and deformation on it. At sudden torque applied by machine, harmonic motion, natural frequency and also loads acting on the cutter at varying speed and cutter thickness. The results obtained with the aid of FEM software for stresses are compared with theoretical values of stresses.*

Keyword: *catia, milling, FEM, Ansys*

I. Introduction

Increasing the productivity and the eminence of the machined parts are the main challenges of metal-based industry. There has been increased interest in monitoring all aspects of the machining process. These machines assisted man in maintaining accuracy and uniformity while duplicating parts that could not be manufactured with the use of a file. Development and improvements of the milling machine and components continued, which resulted in the manufacturing of heavier arbors and high speed steel and carbide cutters. These components allowed the operator to remove metal faster, and with more accuracy, than previous machines. Variations of milling machines were also developed to perform special milling operations, Milling is the process of machining flat, curved, or Milling machines are basically classified as vertical or irregular surfaces by feeding the work piece against a rotating horizontal. These machines are also classified as knee-type, cutter containing a number of cutting edges. The milling ram-type, manufacturing or bed type, and planer-type, Most machine consists basically of a motor driven spindle, which milling machines have self-contained electric drive motors, mounts and revolves the milling cutter, and a reciprocating coolant systems, variable spindle speeds, and power-operated adjustable worktable, which mounts and feeds the work piece, table feeds [1,2]. This paper aims to develop an optimum geometric model of a plain cutter based on the application. To overcome the difficulties associated with modeling a complex cutter, an interface in the form of a customized tool design modeler is developed. This design tool can render the three-dimensional geometry of the cutter in any commercial CAD environment for validation and design improvements. In this work, the proposed 3D model of the special shaped milling cutter is used for finite element analysis to optimize its design. The results of stress distribution and deformation are presented.

II. Literature Review

Mohammed and Tandon (2000) developed geometric design model of a brazed insert-based CEFM cutter in terms of three-dimensional (3D) parameters. The model defined the CEFM cutter in terms of 3D rotational angles and also developed a provision of interface of 3D CEFM cutter directly for the purpose of methodology validation. Finite element analysis (FEA) was used to determine the effects on cutting insert under transient dynamic load conditions. [3]
Mohammed and Tandon (2000) proposed a shape design methodology in order to develop the geometry of a generic special shaped milling cutter. The proposed three-dimensional parametric definition of the cutter with varying the rake angle of the insert and insert seat was analyzed using FEM. Though there is a good amount of work is done by the researcher to study and develop the various models for the conventional single point and multipoint cutting tools, but a few works have been recorded on the development of special shaped milling cutter model. [4]

III. Kinds of Milling Cutters

3.1 Plain Milling Cutter*:* The most common type of milling cutter is known as a plain milling cutter. It is merely a metal cylinder having teeth cut on its periphery for producing a flat horizontal surface.

3.2 Metal Slitting Saw Milling Cutter*:* The metal slitting saw milling cutter is essentially a very thin, it is ground slightly thinner toward the center to provide side clearance. It is used for metal sawing and for cutting narrow slots in metal.

3.3 End Milling Cutters: End milling cutters, also called end mills, have teeth on the end as well as the periphery. The smaller end milling cutters have shanks for chuck mounting or direct spindle mounting. Larger end milling cutters are called shell end milling cutters and are mounted on arbors like plain milling cutters. End milling cutters are employed in the production of slots, keyways, recesses, and tangs. They are also used for milling angles, shoulders, and the edges of work pieces.

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3.4 Concave and Convex Milling Cutters: Concave and convex milling cutters are formed tooth cutters shaped to produce concave and convex contours of one-half circle or less. The size of the cutter is specified by the diameter of the circular form the cutter produces.

3.5 Corner-rounding Milling Cutter: The corner-rounding milling cutter is a formed tooth cutter used for milling rounded corners on work pieces up to and including one-quarter of a circle. The size of a cutter is specified by the radius of the circular form the cutter produces, as with concave and convex cutters.

3.6 Special Shaped-formed Filing Cutter: Formed milling cutters have the advantage of being adaptable to any specific shape for special operations. The cutter is made for each specific job. In the field, a fly cutter is made to machine a specific shape.

3.7 T-Slot Milling Cutter: The T-slot milling cutter is used to machine T-slot grooves in worktables, fixtures, and other holding devices. The cutter has a plain or side milling cutter mounted to the end of a narrow shank. The throat of the T-slot is first milled with a side or end milling cutter and the headspace is then milled with the T-slot milling cutter [5]

IV. Design Implementation

In this work, a customized tool design modeler has been developed. This design tool helps in rendering the proposed three-dimensional model, defined with the help of parametric equations, in any CAD environment by suitable translation of the geometric data of the cutter. Developing an interface is advantageous in comparison to using the APIs of existing CAD packages, as it does not limit the convenience of the proposed modeling paradigm, primarily the conversion of free-form parametric surfaces. This also helps in validating the mathematical models,

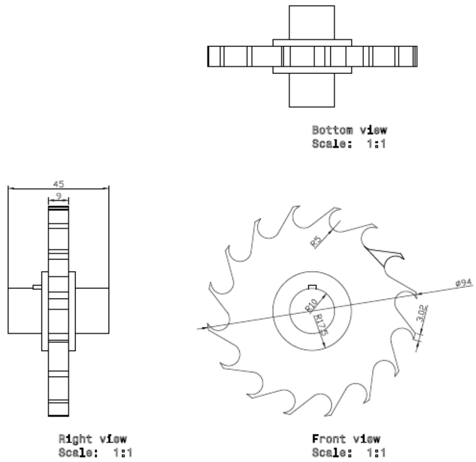

Figure-1

High Speed steel is the material chosen for the milling cutter and the properties are tabulated in Table 1

Table 1
MECHANICAL AND THERMAL PROPERTIES OF TOOL INSERT (HSS)

Materials	High Speed Steel
Density (kg/m3)	7980
Young’s modulus, E (GPa)	210
Poisson’s ratio, n	0.30
Tensile strength (MPa)	970
Thermal conductivity (W/m°C)	20.9

V. Finite Element Analysis of Plain Milling Cutter

In order to perform a finite element analysis, it is necessary to determine the forces acting on the cutter. From the given conditions the force acting on the cutter (W) may be calculated as:

$$W = \frac{60 \times H}{\pi d n} \quad \text{- Equation (1)}$$

Where H is the power, in kW, n is the speed, in rpm, and D is the diameter of the cutter.

The stress calculation at the tip of the tooth of the cutter is estimated based on the concept of gear tooth stresses. The stress at each speed is determined by [6]

$$\sigma = \frac{6Wl}{Ft^2}$$ -Equation (2)

VI. Analysis of Single Tooth Using Ansys

The Cutting Forces on the cutter for different speeds are calculated and the same are applied on the tip of the cutter modal. The variation in stresses and deformation on cutter from ANSYS are Shown in following Figurers. The results are tabulated

Stress at speed 100 rpm thickness 9mm

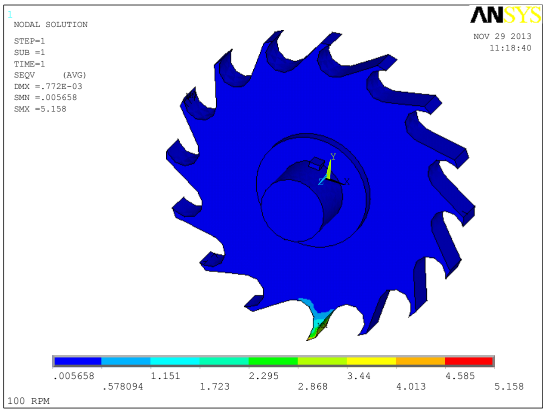

Figure-2

Deformation at speed 100 rpm thickness 9mm

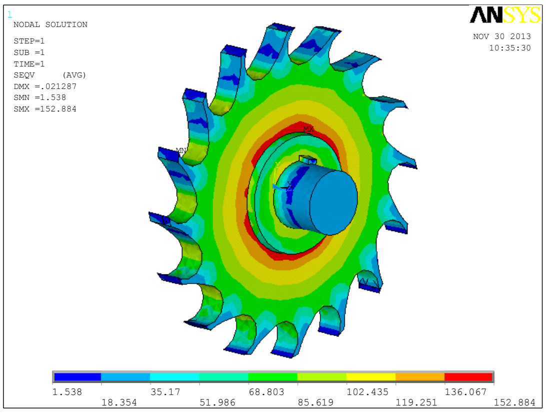

Figure-3

Stress at speed 1600 rpm thickness 9mm

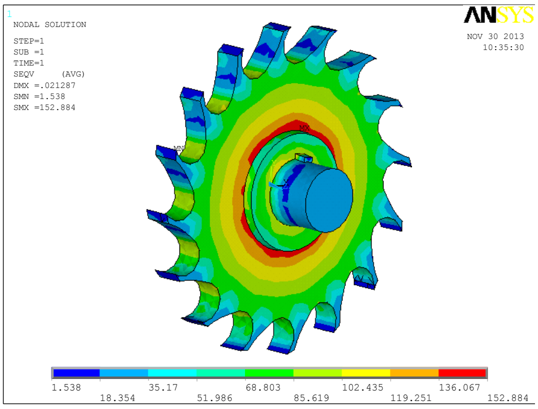

Figure-4

Deformation at speed 1600 rpm thickness 9mm

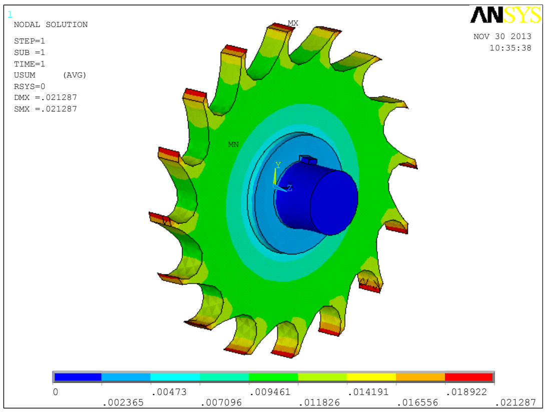

Figure-5

Stress at speed 100 rpm thickness 12mm

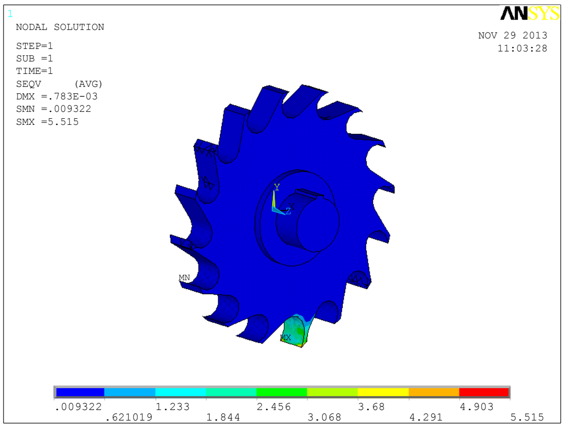

Figure-6

Deformation at speed 100rpm thickness 12mm

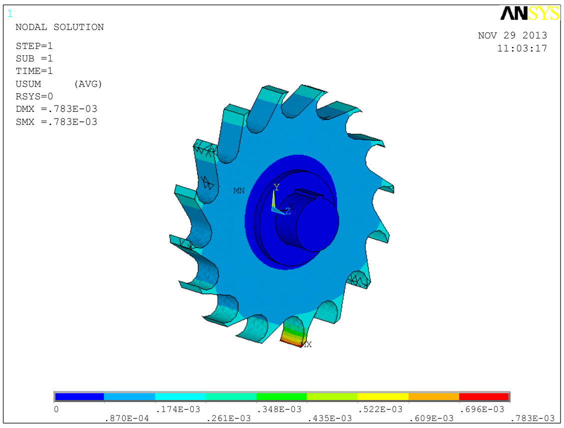

Figure-7

Stress at speed 1600 rpm thickness 12mm

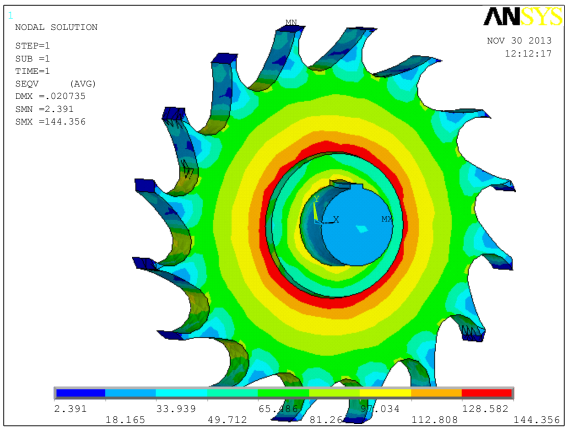

Figure-8

Deformation at speed 1600rpm thickness 12mm

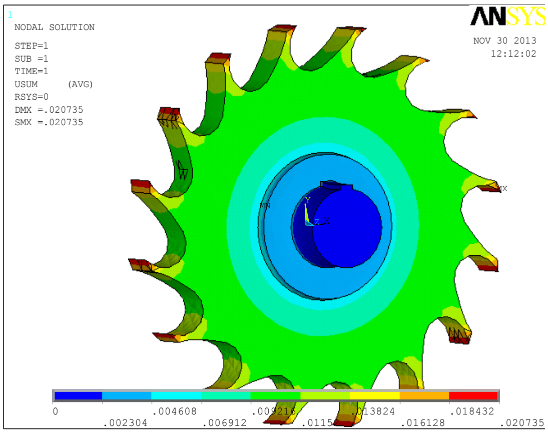

Figure-9

Stress at speed 100 rpm thickness 15mm

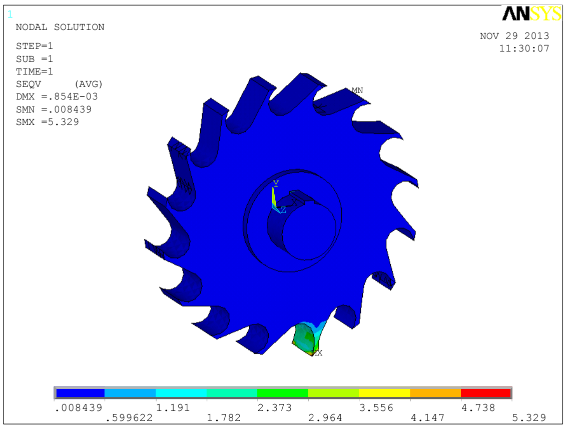

Figure-10

Deformation at speed 100rpm thickness 15mm

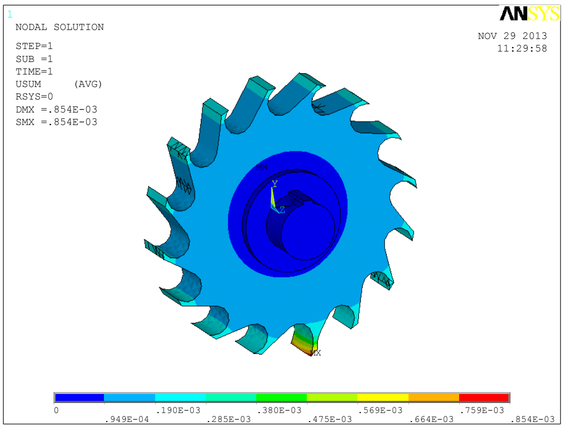

Figure-11

Stress at speed 1600 rpm thickness 12mm

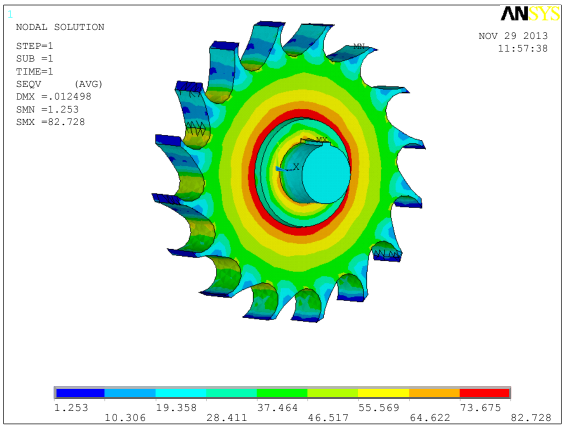

Figure-12

Deformation at speed 1600rpm thickness 12mm

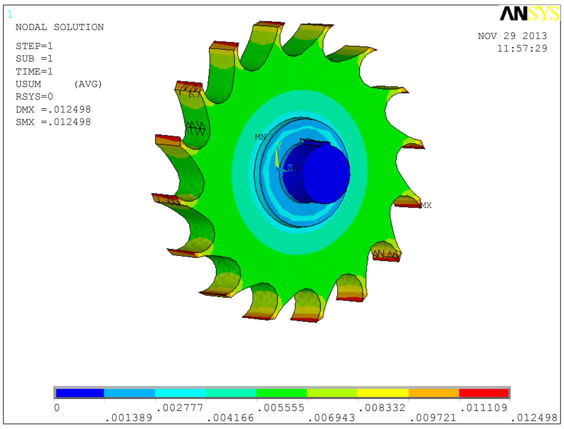

Figure-13

VII. Results Obtained

Table.2

The following results tabulates milling cutter with thickens if 9mm

S.NO	DIA	SPEED	LOAD	STRESS Ansys, Results	STRESS (Theoretical)
1.	94	100	3.0477	5.158	6.528
2.	94	200	1.5238	2.162	3.465
3.	94	300	1.0158	5.054	7.268
4.	94	400	0.7465	8.986	9.458

5.	94	500	0.6095	14.08	15.248
6.	94	600	0.5079	20.218	22.167
7.	94	700	0.4353	27.218	25.748
8.	94	800	0.3809	35.493	38.745
9.	94	900	0.3362	45.49	49.751
10.	94	1000	0.3047	61.916	65.214
11.	94	1100	0.2770	67.913	68.215
12.	94	1200	0.2534	80.875	76.458
13.	94	1300	0.2108	94.912	90.154
14.	94	1400	0.2170	110.74	115.154
15.	94	1500	0.2031	126.359	124.251
16.	94	1600	0.1906	152.884	155.547

Table.3
The following results tabulates milling cutter with thickens if 12mm

S.NO	DIA	SPEED	LOAD	STRESS Ansys, Results	STRESS (Theoretical)
1.	94	100	3.0477	5.515	6.268
2.	94	200	1.5238	3.528	4.258
3.	94	300	1.0158	5.076	8.456
4.	94	400	0.7465	9.021	11.254
5.	94	500	0.6095	14.859	17.987
6.	94	600	0.5079	20.294	24.875
7.	94	700	0.4353	27.622	30.687
8.	94	800	0.3809	36.077	34.567
9.	94	900	0.3362	45.66	49.874
10.	94	1000	0.3047	56.453	54.846
11.	94	1100	0.2770	68.207	65.784
12.	94	1200	0.2534	81.176	79.814
13.	94	1300	0.2108	95.293	97.147
14.	94	1400	0.2170	112.985	116.876
15.	94	1500	0.2031	126.834	120.574
16.	94	1600	0.1906	144.356	150.745

Table.4
The following results tabulates milling cutter with thickens if 15mm

S.NO	DIA	SPEED	LOAD	STRESS Ansys, Results	STRESS (Theoretical)
1.	94	100	3.0477	5.329	6.574
2.	94	200	1.5238	2.808	3.852
3.	94	300	1.0158	5.021	7.154
4.	94	400	0.7465	8.924	10.254
5.	94	500	0.6095	13.924	15.247
6.	94	600	0.5079	20.075	22.946
7.	94	700	0.4353	27.325	30.246
8.	94	800	0.3809	35.689	38.654
9.	94	900	0.3362	45.169	49.854
10.	94	1000	0.3047	55.769	59.624
11.	94	1100	0.2770	67.473	70.487
12.	94	1200	0.2534	80.394	85.124
13.	94	1300	0.2108	94.488	100.523
14.	94	1400	0.2170	108.295	105.781
15.	94	1500	0.2031	125.466	130.847
16.	94	1600	0.1906	82.729	90.657

Graph Represents variation in stress with respect to variation in load for both FEA model and theoretical results for Table.2

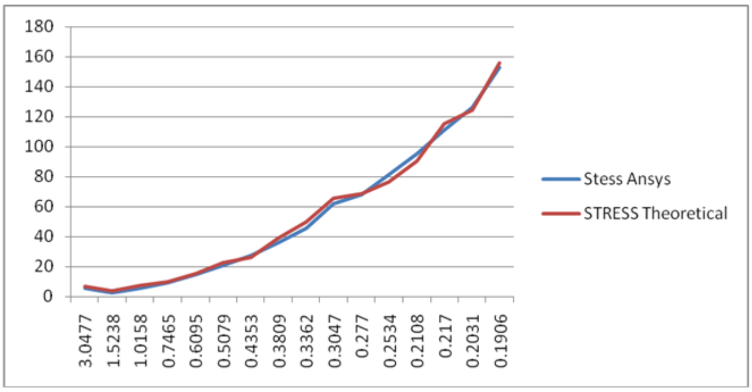

Figure-14

Graph Represents variation in stress with respect to variation in load for both FEA model and theoretical results for Table.3

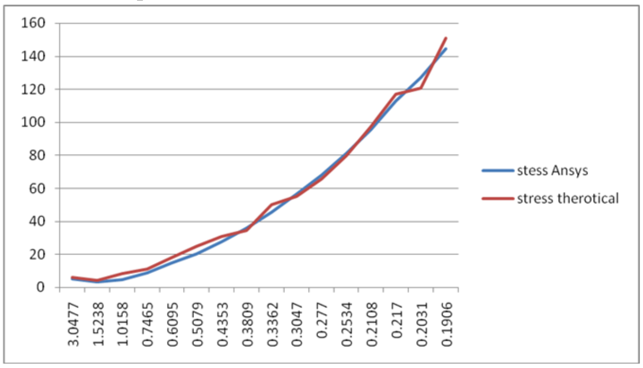

Figure-15

Graph Represents variation in stress with respect to variation in load for both FEA model and theoretical results for Table.4

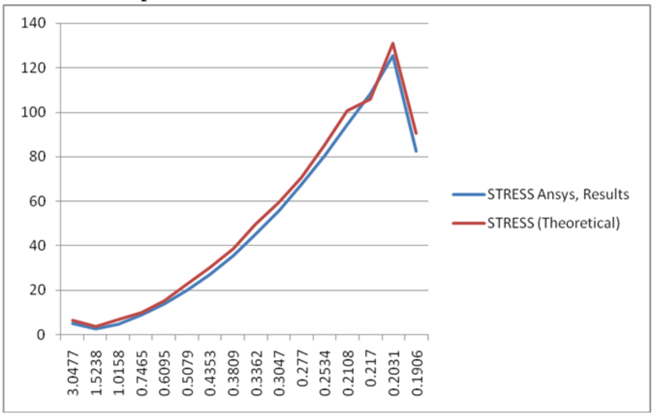

Figure-16

VIII. Findings

- From the Figurers 14 and 15, it is observed that the low values of stresses and deformation are recorded at the combination of 200 rpm and thickness of 9 mm and 12 mm.
- Figurer 16 indicates the lowest value of stresses and deformation at the combination of 1600 rpm and 15 mm thickness.

IX. Conclusions and Discussion

This work illustrates an advanced modeling paradigm that can be used to accurately model a special shaped milling cutter and thus, opens up paths to define conveniently various customized cutters. Here, different design activities, such as geometric modeling, finite element analysis and design improvements have been integrated. As is evident, the approach illustrated in this paper is flexible and easy to use. This approach can also be used to design any complex mechanical component, specifically for the cutter design, it produced the cutting variables that yield the minimum cost of manufacturing. The different design activities, such as design solid modeling, and finite element analysis, have been integrated. The values obtained are compared with the model and theoretical stress values of the special shaped milling cutter. It was observed from the results, both stresses and deformation values were drastically reduced at the combination of 1600 rpm and 15 mm thickness.

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